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Tomato processing, lycopene and health benefits: A review

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Abstract
Tomato and tomato-based products are important source of many established nutrients and phytochemicals that may have health benefits. Lycopene is an important carotenoid found in tomatoes that has recently received attention for its potential role in preventing various degenerative diseases in humans. Tomatoes are used in many processed items like tomato and spaghetti sauce, tomato soup, ketchup, and tomato paste. This review summarizes the background information about tomato composition, lycopene health benefits and effect of processing on the various attributes of tomato products.
Keywords: Tomato, lycopene, health benefits, processing

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Introduction

The tomato is one of the most popular fruits of the earth. Although it is categorized as a vegetable, but in botanical terms, the tomato is the fruit born on a vine. Water content of tomato is quite high and is about 93-95%. The solid matter content of tomato ranges from 5.5-9.5% of which about 1% is seed and skin (on fresh weight basis). There are a number of reasons behind this varied range of solids percentage in tomato composition, like variety, rainfall, soil characteristics and irrigation [1]. The insoluble solids in tomato juice ranges from 15-20% of total solids and mainly composed of lignin cellulose and pectin [2]. Free sugars constitute the main part of soluble solids. The reducing sugars are predominant free sugars of tomato [3]. Sucrose is found in tomatoes in very negligible quantity and is not more than 0.1%. The glucose and fructose are main reducing sugars that make up 50-65% of tomato solids. The total sugar content of tomato varies from 2.19-3.55% [4]. Tomato contains more fructose than glucose (54:46) [2]. Tomato contains various polysaccharides like xylan, pectin, cellulose, arabinoxylan and arabinogalactan. These polysaccharides are about 0.7% of tomato juice. Among polysaccharides, arabinogalactans and pectin are in highest amount and constitute about half of total polysaccharides present, while cellulose and xylans are 25 and 28 per cent of total polysaccharides, respectively [3].

Citric acid as citric monohydrate is the dominant acid in tomato. Tomato also contains a small fraction of other acids like succinic, oxalic and tartaric acid. The amino acid profile of tomatoes shows that it contains nineteen amino acids. Amino acid that is in highest concentration in tomato juice is glutamic acid, and is almost half of its total amino acid contents. Aspartic acid is the second most abundant amino acid after glutamic acid. Tomato juice is deficient in proline [3]. Iron is the most important among the minerals present in tomato, in term of providing adequate nutrition. Tomato contains iron that is more bioavailable because of ascorbic acid, that is present in appreciable quantity in tomato and keep the iron in its reduced form. A glass of tomato juice can meet 10-20% recommended daily allowance of iron [5].

Pinela et al. [6] conducted a study on nutrition and antioxidant composition of four tomato varieties. The components that they analyzed included macronutrients, hydrophilic (anthocyanins, phenolics, vitamin C and flavonols) and lipophilic (lycopene, β-carotene and tocopherols) antioxidants and sugar profile by chromatographic techniques. Round tomato variety was found to be more powerful in antioxidant activity (EC50 values ≤1.63 mg/ml), phenolics 31.23 mg gallic acid/g extract, anthocyanins 3.45mg ME/g extract, flavonols 6.36mg Quercetin/g extract and carotenoids (lycopene 9.49mg/100 g and β-carotene 0.51mg/100g), while another variety named yellow tomato was found to have higher total tocopherols (1.44mg/100g), fructose (3.42g/100g), α-linolenic acid (15.53%) and glucose (3.18g/100g) levels. Antioxidants that are present in tomatoes are vitamin C (160-240mg/kg), provitamin A carotenes (6-9mg/kg), lycopene (30-200mg/kg), phenolic compounds like flavonoids (5-50mg/kg) and phenolic acids (10-50mg/kg) [7]. Tomatoes contain vitamin E, which ranges from 5-20mg/kg of tomatoes. Some important minerals are also present in tomatoes, which are essential for the synthesis of some antioxidant enzymes. Among these minerals, zinc ranges from 1-2.4mg/kg, copper 0.1-0.9mg/kg and manganese 1-1.5mg/kg of tomatoes [8].

When the tomato is at peak maturity stage, then almost all of its vitamin C is converted into reduced state. In tomato, dehydro-ascorbic acid is present in quantity less than 5% of the total ascorbic acid [9].

Red tomatoes contain 25mg ascorbic acid/100g of tomatoes by weight. In this way, tomatoes are a valuable source of ascorbic acid that helps to protect our body from various diseases. Tomato can meet easily 40 % of an adult's body requirement by providing 60mg of ascorbic acid and 2/3rd of the children's daily requirement that is about 40mg per day [8]. Tomato contains significant quantity of β-carotene that has vitamin A activity. This small amount of tomato can easily meet the 20% daily requirement of an adult's body. Some vitamins of the B group are also present in tomatoes among these vitamins; thiamine is present in concentration ranges from 60-120mg per 100g of ripe tomato and tomato juice [2]. While riboflavin and niacin contents of the tomato are comparatively low, 20-50mg riboflavin per 100g of tomato and <1 mg in case of niacin [4]. Lycopene is one of the most important carotenoid present in red tomato. Lycopene formation occurs at the last stage of tomato ripening. The other carotenes that are present in tomato are in lower concentration than that of lycopene, which is about 85% of total carotenoids. Sandei et al. [10] found a range of lycopene between 2-3.4 g/kg of dry matter through several commercially processed tomato lines.

Behavior of nutrients during tomato processing

Amino acids

Processing of tomato juice at temperature above 100 °C for 20 minutes causes remarkable rise in amino acid contents owing to partial hydrolysis and protein denaturation. The highest increase in the concentration was found in glutamic acid followed by aspartic acid, threonine and alanine. Some amino acids like glutamine and asparagine lost completely during processing due to their conversion into respective acids [3].

Vitamins

Ascorbic acid is destroyed in tomato processing, mainly by oxidation. Several factors affect the rate of oxidation of ascorbic acid such as dissolved copper, oxygen, enzyme and processing temperature. Studies have shown that destruction of ascorbic acid is directly related with temperature and air [8]. Later work showed that retention of ascorbic acid for both pre-heating processes (hot and cold) is almost same if the juice is not held in open air at a higher temperature for a considerable time period [11]. Prolonged heating of tomato juice in open air causes the destruction of retinol and some vitamins of B group [8].

Lycopene

Information regarding the effect of processing on lycopene showed that lycopene is quite stable in tomato processing and storage [8]. Lycopene may be degraded by long term exposure to oxygen, low water activity and quite high processing temperature. However, researchers substantially agree that this compound is very stable in commercial production/processing, in term of both degradation and isomerization [12].

Reducing sugars

During heat treatment, the amount of reducing sugar decreases due to various chemical reactions like caramelization, Maillard reaction, and the formation of 5-hydroxymethyl furfural. The amount of sugar lost depends on the type of the process used. Studies have reported as much as 19% loss of reducing sugars in processed tomato juice [3].

Acids

The acid content of tomato increases during its processing into juice. An increase in the concentration of acetic acid was observed up to 32.1%. There may be several reasons for this increase in acid content like oxidation of alcohols, aldehyde and some other compounds. It is considered that breakdown of amino acids into its respective components is the major reason of increased acid content in processed tomato. An increase in other acids like citric and malic was also observed in tomato juice [3]. Gancedo and Luh, [13] found that the acidity of hot break juice is less than the cold break juice. Fonseca and Luh, [14] observed that pH of hot break juice was higher than cold break juice.

The effect of processing on sensory properties of tomato

Color

During processing, color of tomato paste may be slightly darkened due to initiation of browning reactions. These reactions are not so important in term of decreasing quality because they cause the red pigment formation that eventually adds up red color of tomato paste [15]. There are a number of reactions that cause browning of tomato paste like Maillard reaction and caramelization. Caramelization may occur due to high temperature during processing. However, the Maillard reaction is not a major issue during processing of tomato juice into paste [16]. Ascorbic acid is in considerable amount of tomatoes and its breakdown during processing is considered as a main

factor to darken serum color [17]. However, browning can be minimized, by decreasing pH and temperature during processing.

Flavor

Processing alters completely the aroma of processed tomato from the fresh ones. It may be due to loss of compounds that are volatile in nature due to high temperature during processing or due to formation of new compounds. Processing of tomato juice at higher temperatures in open air causes the production of terpenes due to the oxidation of carotenoids. Some sulphurous and carbonyl compounds can also produce during processing as a result of the Maillard reaction. Cis-3-hexenal and hexenal, important compounds that give typical tomato flavor lost during processing [18]. Conversion of Cis-3-hexenal to trans-2-hexenal is an important factor that contributes towards loss of tomato flavor [19]. Cooked odor in processed tomato may be contributed by the compounds formed through the breakdown of sugar and carotenoids. Dimethyl sulphide is the major contributor to the aroma of heated tomato products [18, 20, 21]. Lipoxygenases that gives typical flavor to tomato are degraded during the heating process [22].

Lycopene and its health importance

Lycopene

Lycopene is a carotenoid that can only be synthesized by plants and not by animals. It is an acyclic isomer of β-carotene, but without vitamin A activity [23, 24]. It is a straight chain hydrocarbon, which is highly unsaturated and contains two non-conjugated and 11 conjugated double bonds. Recently, it is getting more attention due to its antioxidant properties [23, 25, 26].

Sources

In contrast to other carotenoids, it is present in a very limited number of fruits and vegetables. The most common sources of lycopene are tomato, watermelon, pink guava, pink grapefruit and apricot [23, 26]. Tomato and processed tomato products are a good source of lycopene. Its quantity is affected by tomato variety and ripening stage [27].

Occurrence in plants

Lycopene exists predominantly in most thermodynamically stable trans-configuration in plants. Chemical reactions, light and thermal energy may cause its cis-trans isomerization [26, 28].

Occurrence in human plasma

In human plasma, it occurs as an isomeric mixture with 50% cis and 50% trans isomers. The most commonly identified forms of lycopene are 15-cis, 13-cis, 9-cis, 5-cis and all *trans* forms [29]. Clinton et al. [29] also observed high concentration of the cis isomers in human serum and prostate tissues. It is the predominant carotenoid in human plasma [30, 31] and in various tissues [29, 32].

Lycopene bio-availability

Lycopene is poorly absorbed in its natural trans form that is present in raw tomatoes. Recently, many studies have shown that heat processing of tomato into various products like tomato paste, ketchup and sauces induce isomerization of lycopene from *trans* to *cis* configuration and hence increases its bioavailability [24]. A negligible increase in plasma lycopene level was observed after consumption of unheated tomato juice [24, 33]. However, when oil was mixed with heated tomato juice and consumed, then plasma lycopene concentration was found to increase after 24-48hr of ingestion [24]. Lycopene absorption and its bioavailability depend upon fat content of the meal, processing of lycopene containing food and heat induced isomerization [23, 34, 35].

Health impacts of lycopene

Various chronic diseases may occur due to oxidative damages caused by reactive oxygen species (ROS) [36-39]. Lycopene is the most efficient quencher of these free radicals and singlet oxygen species and hence have a potent role in the protection of various diseases [40-43]. Thus biochemical properties of lycopene enable it to protect cellular components against the damage caused by reactive oxygen species. These reactive species may be formed by chronic inflammation, sunlight, temperature and by normal metabolic process [44-46].

Antioxidant properties of lycopene may prevent atherogenesis and carcinogenesis by protecting DNA, lipids, low density lipoprotein (LDL) and proteins [47-49]. Oxidation of LDL is said to be the major reason behind atherosclerosis, which carries cholesterol into the blood stream and leads to ischemic stroke and heart attack [38, 50].

Protection of cancer by lycopene

Giovannucci [51] reviewed 72 epidemiological studies on tomatoes, lycopene and their impact on various cancers. A large number of studies showed an inverse relation between plasma lycopene level and cancer. He obtained strongest evidences about lycopene in decreasing the cancers of prostate,

stomach and lungs. Lycopene association in decreasing the risk of other types of cancers like pancreas, oesophagus, rectum, colon, oral mucosa, cervix and breast was only suggestive.

Protection from lung cancer

Cigarette smoke has high level of nitric oxide (NO) that reacts with oxygen to form NO_2 free radical. These radicals retain in smoke and reach to the lung tissues and may cause lung cancer after long term exposure [52]. The major carotenoid found in the lungs is lycopene [53]. It helps to protect lymphocytes from damage caused by NO_2 radical and its ability to quench singlet oxygen is also twice as high as β-carotene [54]. This carotenoid has also proven anti-cancerous properties in carcinogenesis model of mouse lung studies [55].

Prevention of cardiovascular disease

Lycopene causes an increase in LDL receptors so ultimately decreases the cholesterol formation. *In vitro*, lycopene resulted in a decrease of about 73% cholesterol synthesis and about 34% increase in LDL degradation, and also increased about 110% removal of LDL from circulation [56]. Lowering the cholesterol means lowering the risk of heart diseases. Peto et al. [57] found 3:1 ratio between reduction in cholesterol level and decrease in risk of myocardial infarction. It means there is 30-40% reduction of the risk of cardiovascular disease in a person taking lycopene regularly.

Conclusions

This review describes the impact of processing on the nutritive and sensory properties of tomato. It is believed that processed fruit and vegetables have lower nutritional value, but it does not happen always. Processing may result an increase in bioaccessible lycopene, total antioxidant activity and amino acids. The benefits of tomato and tomato products are mainly contributed by lycopene. Intake of tomato and its products increases plasma lycopene concentration and associated with a lower risk of a variety of diseases.

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